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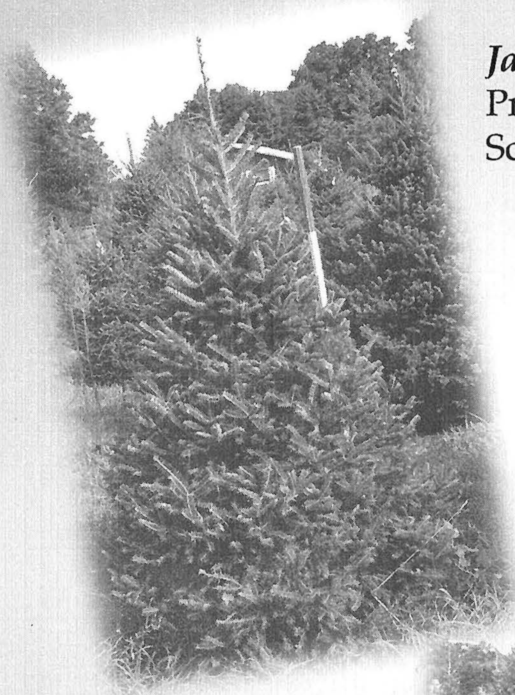

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Introduction and Background

Shearing is one of the most important cultural practices affecting production of high-quality Christmas trees. After an initial establishment period of two to four years, during which seedlings are developing an extensive root system, trees usually grow so rapidly that long internodes between whorls of limbs and laterals of varying length give trees an open, irregular appearance. Without shearing and shaping, a very small percentage of trees will be of salable quality.

The multi-needled pine species used for Christmas trees in Ohio usually do not have internodal buds between the major whorls of limbs on unsheared trees. Rather, there are dormant, fasicular buds located in the base of the individual needle bundles along the stem which generally do not develop unless the terminal buds on individual stems are removed (Figure 1). Research has shown that to obtain good results, trees of the pines should be sheared soon after shoot growth is completed,

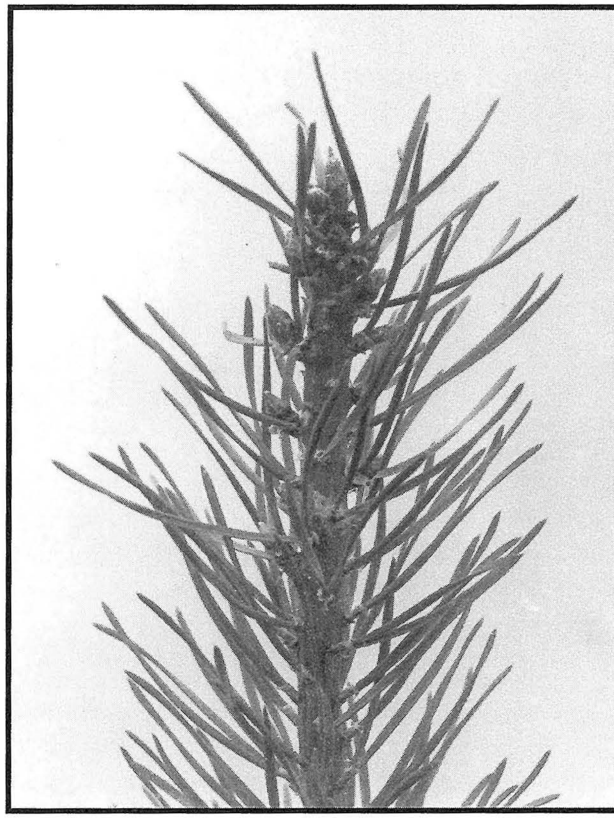

Figure 1. Interfascular buds developing at base of needle bundles on sheared Scotch pine.

usually in early- to late-June in Ohio for Scotch pine (*Pinus sylvestris*), white pine (*Pinus strobus*), red pine (*Pinus resinosa*), and Austrian pine (*Pinus nigra*). When trees are sheared later in the summer and into the fall and winter, fewer buds develop at the base of needle fascicles on cut stems, and shoot growth and the number of effective whorl limbs that develop the following year become progressively less.

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White pine shoots sheared too late in the year may not form new buds and cut stems die back.

How trees are sheared is also very important. Even if they are sheared at the proper time, tree size and quality are affected by shearing techniques. The length to which the terminal shoot is cut is particularly important because the basic outline and taper of the tree is generally shaped to conform to the length of the leader. Obviously, terminals should be cut as long as possible so that marketable-sized trees can be grown in the shortest possible time; however, if shoots are too long, tree quality may be affected (Brown, 1960; Brown, 1964; Brown, 1981; Brown, 1984).

Unlike the pines, the "single-needled" conifer species — firs (*Abies* sp.), spruces (*Picea* sp.) and Douglas-fir (*Pseudotsuga menziesii*) — do not have fasicular buds at the base of needles but have internodal or "side" buds along the stems between major whorls of limbs, most of which are pre-set and clearly visible after shoot growth has been completed (Figure 2). Although most of those buds develop into internodal, lateral limbs, those limbs often remain relatively small on uncut stems, while on stems that have been cut, they grow into longer and stronger limbs that help to cover open areas and give trees a more uniform, dense appearance.

The quality of trees of the single-needled species can also be affected by the lengths to which terminal shoots are cut; however, effects of time of shearing are less well documented. In a study with Norway spruce (*Picea abies*), trees were sheared in July, October, January, and April in each of five years (Brown and Tryon, 1961). Tree quality was improved considerably as the number of annual shearings increased, but

Figure 2. Internodal buds and limbs on West Virginia balsam (left) and Frazer fir (right) terminal shoots.

no pronounced differences were noted between times of pruning, except in one year when lateral limbs developed from internodal buds on cut stems of some of the trees sheared in July and an additional light shearing was needed to correct irregularities in tree shape. Although most Christmas tree growers currently shear single-needled conifers from fall through the following spring before new shoot growth begins, some shear in mid- to late-summer.

While Scotch pine and white pine continue to make up a high percentage of the Christmas trees planted and harvested in Ohio, that percentage has declined in recent years. Concurrently, planting and harvesting of trees of the single-needled conifers have been increasing.

From 1984 to 1996, the percentage of Fraser fir (*Abies balsamea* var. *fraseri*) planted more than doubled to approximately 12 percent of the total, and harvesting tripled, also to approximately 12 percent. In addition, trees of West Virginia balsam (Canaan) fir (*Abies balsamea* var. *phanerolepis*), which were introduced into Ohio plantings in the late 1980s, made up approximately 8 percent of the planting and approximately 5 percent of the harvest in 1996 (Brown, 1983a; Heiligmann and Passewitz, 1998).

The purposes of the research reported here were to study the effects of time of shearing and length of terminal shoots on the development and quality of West Virginia balsam and Fraser fir Christmas trees. In addition, the effects of annual applications of nitrogen fertilizer on tree development and quality were evaluated.

Methods

Trees used in this study were planted in April 1993 at a spacing of 5 feet between trees in rows and 8 feet between rows. The planting was located on a site at The Ohio State University's Ohio Agricultural Research and Development Center (OSU/OARDC) campus at Wooster. Plugs + 2 planting stock of West Virginia balsam fir of a Canaan Valley seed source and 2 + 2 planting stock of Fraser fir of a Roan Mountain, North Carolina seed source were planted in blocks adjacent to each other. The site was relatively level with well-drained Wooster series and moderately well-drained Canfield series soils.

Weed control in the plantings included preplanting spraying of three-foot wide strips with glyphosate (2.5 pounds a.i.a.), followed by annual applications of simazine and atarazine (2 pounds a.i.a. each). Areas between rows were mowed two to four times per year.

In August 1996, trees in the blocks of each variety were divided into sub-plots using a randomized complete block experimental design to provide three-tree plots and four replications of each of the eight treatment combinations shown in Table 1. To conform with the statistical design, treatments were assigned randomly to individual three-tree plots without regard to growth rate, numbers of internodal terminal shoot buds, or branch angles, all of which could substantially affect individual tree response to different shearing treatments.

Beginning with Treatment 1, trees on individual plots were sheared at the designated times, with leader lengths as indicated, and side limbs sheared to provide uniform shape and taper. When terminals on individual trees were not long enough

Table 1. Treatment Combinations for Shearing Study with West Virginia Balsam (Canaan) and Fraser Fir.

Number	Leader Length	Time of Shearing	Fertilization
	inches		200 lbs N/ac/yr
1	10	November	No
2	12	August	No
3	12	November	No
4	12	November	Yes
5	12	March	No
6	15	November	No
7	Progressive[1]	November	No
8	Unsheared	None	No

[1] Treatment 7, Progressive: Trees designated to be sheared to leader lengths of: 1st year = 18 inches; 2nd year = 14 inches; 3rd and 4th years = 12 inches; 5th year = length to give an even, conical appearance to trees.

to permit cutting to the designated length, they were left as long as possible by cutting to a point just above the first, large, internodal bud below the growing tip. In addition, trees in Treatment 4 were fertilized annually in March with ammonium nitrate at a rate of 200 pounds of actual N per acre.

Before trees were sheared the first time, total heights and terminal lengths of trees were measured; after leaders were sheared to appropriate lengths, internodal buds on the cut leaders were counted. When trees were sheared in succeeding years, numbers of internodal lateral limbs that developed from buds on previously sheared terminal shoots were counted and, again, new terminal shoots were measured before shearing to appropriate lengths and bud counts were made on those cut terminals.

In early September of 1997 and 1999, average needle lengths and oven-dry weights of stems and needles were determined from two four-inch-long foliage samples collected from each tree in individual plots. Needles from samples were ground and analyzed for total nitrogen by the School of Natural Resources Service Testing and Research (STAR) Laboratory at the Ohio Agricultural Research and Development Center (OARDC).

In December 1997 and 1999, evaluations were made of the color of the upper surfaces of needles of trees using a subjective rating system of 1 = yellow, 2 = green/yellow; 3 = yellow/green, 4 = green, and 5 = blue/green. In making comparisons, a sample of a single tree that was judged to have yellow/green foliage (rating 3.0) was compared with each individual tree in the study, and a rating was given based on the extent to which foliage color was better or poorer.

At the conclusion of the study in summer 2000, total heights and widths of trees were measured, and foliage density was estimated. In addition, each tree was evaluated for the numbers and locations of minor and major defects (Appendix Table 1) and a USDA grade was assigned to each tree (Appendix Table 2).

Data were analyzed separately for each species using analysis of variance and averages of data for the three-tree plots by OARDC's Computing and Statistical Services. Significant differences between means were separated using least significant difference tests (L.S.D.$_{0.05}$).

As noted previously, the plantings of West Virginia balsam and Fraser fir used in this study were in adjacent blocks in the field, an arrangement that would not permit direct, valid statistical comparisons of similarities or differences between the two in effects of shearing treatments. For some variables where there appeared to be obvious differences between the two, statistical comparisons were made of "locational" differences between the two blocks, which would include not only possible varietal differences but also site and other factors related to the lack of random assignment of variety-treatment combinations to individual plots.

Results and Discussion

As noted, data for each variable was analyzed using averages of measurements or evaluations for the three-tree plots in each replication. The data in Tables 2 to 5, in turn, represent averages for the four replications. As may be seen in those tables, there was considerable variation between the overall averages for some data sets and also year-to-year differences in effects of the different shearing treatments.

Additionally, there was considerable plot-to-plot data variation, as indicated by the relatively large standard deviations and ranges in values (minimums and maximums) for some variables. This is not too surprising, given the natural genetic variation in the varieties and differences in soil characteristics within individual plantings.

Tree Heights and Terminal Shoot Growth

Initial Tree Heights

Trees were established and growing well when the shearing study was begun three years after field planting. Total heights of trees of West Virginia balsam fir and Fraser fir averaged 4.13 feet and 4.23 feet, respectively, and new terminal shoot growth, before shearing, averaged 17.3 and 18.4 inches, respectively. There were no statistically significant differences in total heights or unsheared leader lengths for either variety (Table 2).

Terminal Shoot Growth Before Shearing

Terminal shoot growth before shearing showed decided year-to-year differences. As noted previously, before the first shearing of West Virginia balsam fir trees, unsheared terminal lengths for all trees averaged 17.3 inches, while in subsequent years, they averaged 13.9, 23.6, 15.7, and 20.2 inches, respectively, before the second, third, fourth, and fifth shearings. Similar year-to-year variation was noted for Fraser fir, with lengths of 18.4, 15.7, 22.0, 15.6, and 17.9 inches before the first through fifth shearings (Table 2).

Reasons for this high-low alternating pattern in growth do not appear to be related to treatments. Rather, it may have been related, at least in part, to year-to-year differences in precipitation. Records for the National Oceanic and Atmospheric Administration weather station on the OSU/OARDC campus at Wooster indicate that annual and growing-season precipitation for 1995 (the year prior to the first shearing), 1996, and 1998 were above average, while that for 1997 and 1999 were at or below average. However, for 2000, a year

Table 2. Heights, Terminal Shoot Lengths Before and After Shearing and Final Heights of Trees of West Virginia Balsam (Canaan) and Fraser Fir.

Treatment				Init.	Terminal Shoot Length, inches										Final
					1st Shear		2nd Shear		3rd Shear		4th Shear		5th Shear		
No.	Lead Lgth[1] in.	Time	Fert	Ht. ft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Ht. ft.
					inches										
West Virginia Balsam Fir															
1	10	Nov	No	4.15	17.2	10.0	13.0	10.0	22.2	10.0	14.8	10.0	19.0	10.0	6.65
2	12	Aug	No	4.15	16.6	11.8	12.4	11.2	24.4	12.0	16.8	12.0	20.2	12.0	7.27
3	12	Nov	No	4.28	16.8	11.8	13.6	11.5	22.8	12.0	15.4	12.0	18.4	12.0	7.39
4	12	Nov	Yes[2]	4.18	16.8	12.0	12.0	10.9	24.0	12.0	16.2	12.0	21.0	12.0	7.51
5	12	Mar	No	4.08	16.8	12.0	12.4	11.3	23.4	12.0	16.0	12.0	19.8	12.0	7.23
6	15	Nov	No	4.06	18.4	15.0	15.4	14.7	22.2	15.0	16.0	14.5	21.0	14.2	8.21
7	Prog[3]	Nov	No	4.17	19.0	17.0	14.2	13.2	24.9	12.0	15.2	12.0	20.4	15.2	8.46
8	Unsh	None	No	3.98	16.8	16.8	18.0	18.0	25.2	25.2	15.4	15.4	22.0	22.0	10.50
mean				4.13	17.3	13.3	13.9	12.6	23.6	13.6	15.7	12.5	20.2	13.9	7.89
stand. dev., % mean				10	10	15	19	29	14	32	15	15	17	48	15
minimum				3.7	14	9.8	9	8	14	10	10	10	14	10	6.4
maximum				4.8	20	17.9	19	27	31	27	20	19	29	29	11.4
F test				2.3	1.0	7.7	4.6	6.6	0.6	73.6	0.3	4.9	1.5	17.2	32.1
prob. F				0.07	0.44	<0.01	<0.01	<0.01	0.72	<0.01	0.95	<0.01	0.21	<0.01	<0.01
L.S.D.$_{0.05}$[4]				—	—	1.9	2.9	3.6	—	1.6	—	2.0	—	3.4	0.63
Fraser Fir															
1	10	Nov	No	4.03	17.2	10.0	13.6	10.0	21.4	10.0	17.2	10.0	17.2	10.0	6.80
2	12	Aug	No	4.25	19.0	12.0	13.2	11.6	22.6	12.0	16.0	12.0	18.6	12.0	7.62
3	12	Nov	No	4.08	16.6	12.0	14.2	11.6	21.4	12.0	14.8	12.0	18.0	12.0	7.45
4	12	Nov	Yes[2]	4.35	19.6	12.0	14.4	12.0	20.4	12.0	14.8	12.0	16.6	12.0	7.77
5	12	Mar	No	4.00	18.0	12.0	15.0	11.8	20.8	12.0	17.2	12.0	18.4	12.0	7.71
6	15	Nov	No	4.40	19.2	14.9	18.0	15.0	24.0	15.0	15.6	14.0	18.0	14.5	8.47
7	Prog[3]	Nov	No	4.35	20.2	18.0	16.8	14.0	21.8	12.0	14.8	12.0	20.4	16.0	8.42
8	Unsh	None	No	4.24	17.2	17.2	20.8	20.8	23.4	24.4	15.0	15.0	18.0	18.0	10.40
mean				4.23	18.4	13.4	15.7	13.3	22.0	13.7	15.6	12.0	17.9	13.1	8.08
stand. dev., % mean				9	13	21	21	24	11	32	13	13	11	19	13
minimum				3.6	13	10	10	10	17	10	12	10	12	10	6.6
maximum				5.1	24	18	25	25	28	27	19	16	22	19	10.6
F test				2.2	2.0	32.5	4.2	22.5	1.9	78.1	2.1	7.9	2.2	18.1	23.2
prob. F				0.08	1.7	<0.01	<0.01	<0.01	0.13	<0.01	0.09	<0.01	0.08	<0.01	<0.01
L.S.D.$_{0.05}$[4]				—	—	0.7	3.7	1.9	—	1.1	—	1.4	—	1.7	0.6

[1] Lengths to which terminal shoots were supposed to be cut as part of the study; when unsheared leaders were not long enough to be cut to those lengths, they were left as long as possible by cutting to a point just above the first, large, internodal bud below the gowing tip, resulting in lengths after shearing which, as indicated in the table, were less than those specified.

[2] Trees in Treatment 4 were fertilized with 200 pounds of actual nitrogen/acre in March of each year.

[3] Treatment 7: "Progressive" treatment trees were designated to be sheared to leader lengths of: 1st year = 18 inches; 2nd year = 14 inches; 3rd and 4th years = 12 inches; 5th year = length to give an even, conical appearance to trees.

[4] Least Significant Differences at 5% probability level for comparing differences between treatment means; values are not given for variables where differences were not statististically significant.

in which terminal shoot growth was good, total precipitation through August (when the study was completed) and for April through August were both well below normal, although there were no periods of prolonged dry weather during the growing season.

There were no consistent effects of shearing on new terminal growth measured the year after shearing was done. In 1997, growth on trees of West Virginia balsam and Fraser fir was significantly greater on unsheared than on sheared trees, but there were no significant differences between trees that had actually been sheared using the different time-length-fertilization treatment combinations. In 1998, 1999, and 2000, there were no significant growth effects between sheared and unsheared trees or between those that had been sheared (Table 2).

In previous research with white pine, Scotch pine, and red pine, it was found that shoot growth the year after shearing was significantly less on sheared than on unsheared trees, and the reduction in growth became progressively greater as trees were sheared later into the summer, autumn, and winter after the "optimum" time in mid- to late-June (Brown, 1960; Brown, 1964; Brown, 1984).

Reasons for the differences between the firs used in this study and the pines in those earlier studies are probably related to the fact that when pines are sheared, the dormant, interfascular buds located at the base of needle fascicles must develop fully, either in the current or succeeding growing season, before new shoots can begin to grow (Figure 1). For West Virginia balsam and Fraser fir trees, internodal buds are already present along the shoots (Figure 2).

Lengths of Sheared Terminal Shoots

At the time of the first and subsequent shearings, average lengths of the main leaders (for three tree plots) of unsheared trees were, in all cases, longer than the lengths to which shoots were supposed to be sheared; however, terminals on some individual trees within plots were not long enough to permit cutting to the lengths designated in the study (Table 1). As noted earlier, when that occurred, the main leaders of those trees were left as long as possible by cutting to a point just above the first, large internodal bud below the growing tip.

As would be expected, because shoots were cut to designated lengths ranging from 10 to 18 inches, depending on the specific treatment and year of the study, there were statistically significant differences between lengths of sheared terminal shoots for trees of both varieties in all years (Table 2).

Final Tree Heights

When the study was completed in the summer of 2000, total heights of trees of West Virginia balsam and Fraser fir ranged from 6.65 and 6.80 feet, respectively, for trees on which leaders were sheared to 10-inch lengths (Treatment 1, Figure 3) to 10.50 and 10.40 feet, respectively, for trees that had not been sheared (Treatment 8, Figure 4). For trees on which leaders were sheared to 12-inch lengths at different times of the year (Treatments 2 to 5), there were no significant differences in total heights of either species, with those of West Virginia balsam fir ranging from 7.23 to 7.51 feet and those of Fraser fir from 7.45 to 7.77 feet (Figure 5).

Figure 3. West Virginia balsam (left) and Fraser fir (right) trees with leaders sheared to 10-inch lengths.

Figure 4. Unsheared West Virginia balsam (left) and Fraser fir (right) trees.

 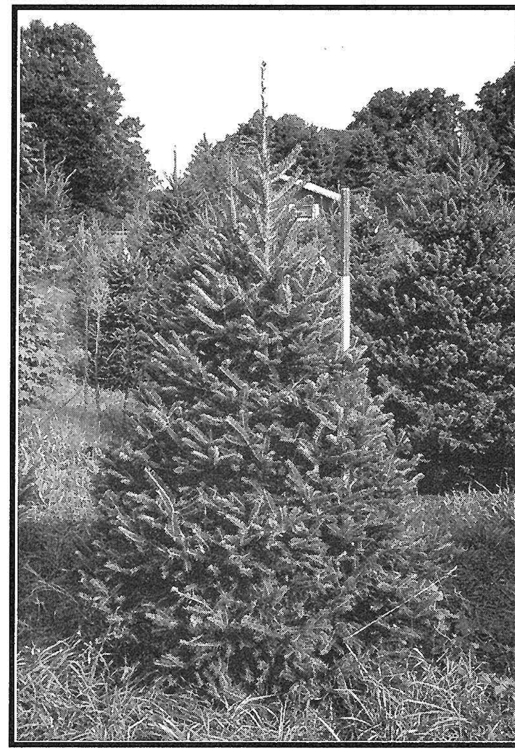

Figure 5. West Virginia balsam (left) and Fraser fir (right) trees with leaders sheared to 12-inch lengths.

Total heights of trees of Treatment 6 (sheared to 15 inches each year) and Treatment 7 ("progressive," with shearing to 18 inches the first year, 14 inches the second, and 12 inches in the third and fourth years) were significantly taller than those of the other treatments in which trees had been sheared (Figure 6), but there was no significant difference between the two (Table 2).

Results of the study indicate that trees sheared consistently to 10-inch leader lengths would begin to reach marketable size, with 6- to 7-foot trees, after five shearings and eight years after planting. For those sheared to 12-inch leader lengths, irrespective of season of shearing or fertilization, trees began to reach the 6- to 7-foot class after seven years in the field, and all trees were in the 7- to 8-foot class after eight years. For trees with leaders sheared consistently to 15 inches and for the "progressive" treatment, trees began to become marketable in the sixth year in the field, and all were in the 8- to 9-foot classes after eight years.

In earlier studies with Scotch and white pine in which leaders were cut to varying lengths over a five-year period, trees with leaders sheared to 10 inches averaged 6.8 and 6.7 feet for white pine and Scotch pine, respectively, while those with leaders sheared to 14 inches averaged 8.6 and 8.2 feet (Brown, 1981).

Numbers of Buds and Lateral Limbs on Terminals

West Virginia Balsam Fir

One of the major factors affecting the quality of single-needled Christmas trees is the number of internodal buds along the terminal shoots between the major whorls of limbs and the number of lateral limbs that develop from those buds (Table 3,

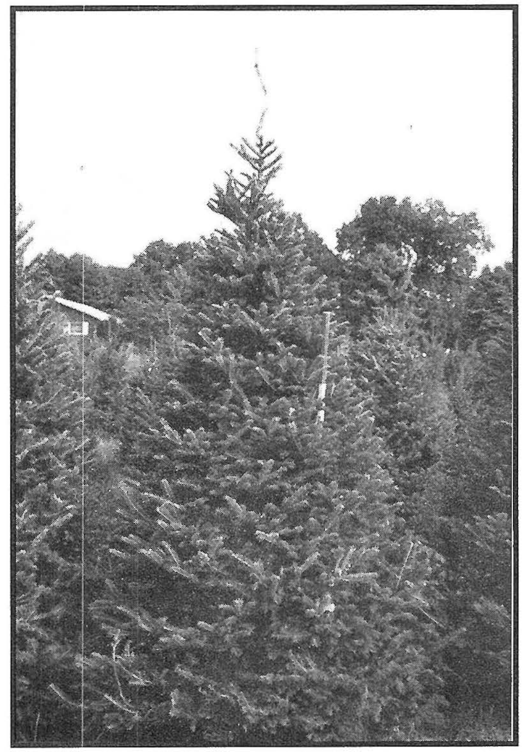

Figure 6. West Virginia balsam (left) and Fraser fir (right) trees with leaders sheared using the "progressive" treatment.

Figure 2). For the West Virginia balsam fir trees used in this study, the number of internodal buds present on cut terminals averaged from 1.8 to 2.6 per inch over the five-year shearing period.

In three of the five years, there were statistically significant differences between treatments in average numbers of buds on shoots; however, there were no consistent patterns in numbers related to whether terminals were or were not cut, the lengths to which leaders were sheared, time of shearing, or fertilization. For the different years, lateral limbs on sheared shoots averaged slightly less than numbers of internodal buds; this same pattern of fewer limbs than buds on trees receiving different shearing treatments was also evident, although there were some exceptions for different treatments and / or years.

Fraser Fir

The numbers of internodal buds and limbs on terminals of Fraser fir were consistently lower than for West Virginia balsam fir, with average numbers for the different years ranging from 1.4 to 1.7 per inch (Table 3, Figure 2). Similarly, numbers of internodal lateral limbs were generally less, averaging from 1.0 to 1.5 per inch. This pattern of fewer limbs than buds on trees receiving the different treatment combinations was also evident, although again there were some exceptions.

A comparison of the differences in buds and lateral limbs on West Virginia balsam and Fraser fir (as described in locational effects in the *Methods* section) indicated that those differences were probably statistically significant. Other studies also found higher numbers of buds and lateral limbs

Table 3. Numbers of Buds and Lateral Limbs on Terminal Shoots of West Virginia Balsam (Canaan) and Fraser Fir.

Treatment				1st Sh.		2nd Sh.		3rd Sh.		4th Sh.		5th Sh.
No.	Lead. Lgth[1] in.	Time	Fert.	Buds/ Inch	Lmbs/ Inch	Buds/ Inch	Lmbs/ Inch	Buds/ Inch	Lmbs/ Inch	Buds/ Inch	Lmbs/ Inch	Buds/ Inch
				-----	-----	-----	-----	number	-----	-----	-----	-----
West Virginia Balsam Fir												
1	10	Nov.	No	2.5	2.1	2.1	1.9	2.2	2.0	2.5	2.3	2.2
2	12	Aug.	No	1.9	2.1	2.0	2.0	1.8	2.1	2.3	2.4	1.9
3	12	Nov.	No.	2.1	1.6	2.3	2.1	2.1	2.1	2.2	2.0	2.0
4	12	Nov.	Yes[2]	2.2	1.7	2.0	1.9	2.2	2.2	2.3	2.1	2.6
5	12	Mar.	No	1.9	1.9	2.1	1.8	2.7	2.3	2.1	1.9	2.3
6	15	Nov.	No	1.9	1.7	1.8	1.8	2.1	1.8	2.4	1.8	1.9
7	Prog.[3]	Nov.	No	1.5	1.7	2.0	1.9	2.3	1.9	1.9	1.8	2.0
8	Unsh.	None	No	1.8	1.7	2.0	1.9	2.0	1.7	2.6	2.1	1.9
mean				2.0	1.8	2.0	1.9	2.2	2.0	2.3	2.0	2.1
stand. dev., % mean				18	17	18	17	16	23	16	18	18
minimum				1.2	1.4	1.0	1.3	1.7	0.8	1.5	1.3	1.0
maximum				2.7	2.5	2.7	2.6	3.1	2.8	3.2	2.7	2.7
F test				3.5	1.5	0.5	0.3	3.5	3.8	2.7	2.4	2.8
prob. F				0.01	0.23	0.85	0.94	0.01	0.01	0.04	0.06	0.04
$L.S.D._{0.05}$[4]				0.43	—	—	—	0.40	0.50	0.43	—	0.46
Fraser Fir												
1	10	Nov.	No	1.7	1.3	1.5	1.3	1.5	1.5	1.8	1.4	1.7
2	12	Aug.	No	1.6	1.0	1.4	1.3	1.3	1.6	1.7	1.7	1.6
3	12	Nov.	No	1.4	1.1	1.7	1.6	1.5	1.4	1.5	1.4	1.6
4	12	Nov.	Yes[2]	1.7	1.0	1.7	1.6	1.6	1.7	1.9	1.8	1.7
5	12	Mar.	No	1.4	1.0	1.3	1.2	1.3	1.2	1.4	1.3	1.5
6	15	Nov.	No	1.4	0.8	1.7	1.5	1.4	1.3	1.5	1.3	1.5
7	Prog.[3]	Nov.	No	1.2	0.9	1.8	1.8	1.7	1.6	1.8	1.5	1.5
8	Unsh.	None	No	1.3	1.4	1.3	1.3	1.3	1.4	1.7	1.4	1.5
mean				1.4	1.0	1.6	1.4	1.5	1.4	1.7	1.5	1.6
stand. dev., % mean				24	23	20	21	16	16	21	19	18
minimum				0.8	0.6	1.0	0.9	1.0	0.9	1.0	0.9	1.0
maximum				2.1	1.6	2.2	2.2	1.9	1.9	2.8	2.2	2.1
F test				2.3	5.5	2.2	3.2	2.8	7.6	1.0	2.2	2.1
prob. F				0.07	<0.01	0.78	0.02	0.03	<0.01	0.47	0.07	0.09
$L.S.D._{0.05}$[4]				—	0.24	—	0.34	0.29	0.19	—	—	—

[1] Lengths to which terminal shoots were supposed to be cut as part of the study.

[2] Trees in Treatment 4 were fertilized with 200 pounds of actual nitrogen/acre in March of each year.

[3] Treatment 7: "Progressive" treatment trees were designated to be sheared to leader lengths of: 1st year = 18 inches; 2nd year = 14 inches; 3rd and 4th years = 12 inches; 5th year = length to give an even, conical apearance to trees.

[4] Least Significant Differences at 5% probability level for comparing differences between treatment means; values are not given for variables where differences were not statistically significant.

on terminal shoots of West Virginia balsam than on Fraser fir (Brown, 1983b; Brown, 1999).

Foliage Characteristics of Trees

Needle lengths, foliage weights, foliar N content of needles, and foliage color of trees of both West Virginia balsam and Fraser fir showed no significant effects related to time of shearing or lengths to which terminal shoots were sheared.

However, fertilization with 200 pounds of nitrogen each year did affect foliage characteristics of trees. Needle lengths were significantly longer in the second and fourth years of the study for both varieties, with those on fertilized trees averaging 24.1 and 23.8 mm in the two years for West Virginia balsam fir and 21.2 and 21.3 mm for Fraser fir. On unfertilized trees, needles were generally 2 to 3 mm shorter for West Virginia balsam and 1 to 2 mm shorter for Fraser fir.

Similarly, weights of twigs and needles were consistently heavier, although not statistically so, on fertilized trees. For both species, foliar N content was significantly higher on fertilized trees in both years. In addition, colors of the upper surfaces of needles of both species were significantly better on fertilized trees, averaging from 4.00 to 4.15 (at or slightly above the "green" rating), while on unfertilized trees color ranged from 3.48 to 3.60 (yellow/green) for West Virginia balsam and 3.69 to 3.83 (yellow/green to green) for those of Fraser fir (Table 4).

In previous studies, nitrogen fertilization of Fraser fir (Brown, 1976; Keller, 1980) and West Virginia balsam fir (Brown, 1998a; Brown, 2000a) did not significantly affect shoot growth of trees but did result in increased needle lengths, foliage weights, foliar N content, and improved foliage color.

The color of the lower surfaces of needles of trees, particularly as influenced by the number and coloration of stomatal bands, can have a distinct influence on the appearance of trees. That characteristic was not evaluated as part of this study. However, it was observed that the underside of the needles of Fraser fir had a distinctive and consistently "bluish" appearance, while those of West Virginia balsam fir were generally more variable, with color ranging from a "grayish" to "moderately bluish." Similar results have been noted in other studies (Brown, 1998a; Brown, 1999; Brown, 2000a).

One other result of interest was average weights of stems and needles. Overall averages for stems of four-inch-long samples of West Virginia balsam were approximately 4.5 grams in each of the two years when samples were collected, as compared to more than 5.5 grams for Fraser fir. For needles, average weights (approximately 3.5 grams) were considerably less for West Virginia balsam than those of Fraser fir (more than 4 grams), despite the fact that needles of West Virginia balsam trees were longer (Table 4). These heavier weights, particularly for Fraser fir twigs, may in part account for the sturdier, less flexible limbs on Fraser than on West Virginia balsam trees.

Tree Quality and USDA Grades

Tree Taper

Taper (width/height) is one of the factors considered in determining the USDA grade

Table 4. Foliage Characteristics of Trees of West Virginia Balsam (Canaan) and Fraser Fir.

						Foliage Weights[2]						Foliage	
Lead.				Needle Length		Twigs		Needles		Foliar N		Color	
No.	Lgth.[1]	Time	Fert.	2nd yr	4th yr	2nd yr	4th yr	2nd yr	4th yr	2nd yr	4th yr	2nd yr	4th yr
				------mm-----		--------------gms--------------				-------%------		----Rating[3]---	
West Virginia Balsam Fir													
1	10	Nov.	No	20.6	21.5	4.38	4.45	3.45	3.50	1.72	1.68	3.50	3.54
2	12	Aug.	No	21.3	21.5	4.48	4.45	3.70	3.78	1.68	1.61	3.53	3.62
3	12	Nov.	No.	20.7	20.8	4.50	4.40	3.70	3.73	1.71	1.60	3.61	3.58
4	12	Nov.	Yes[4]	24.1	23.8	4.85	4.83	3.88	3.95	1.92	1.90	4.10	4.00
5	12	Mar.	No	21.4	21.5	4.71	4.60	3.60	3.63	1.71	1.70	3.62	3.65
6	15	Nov.	No	21.0	21.8	4.50	4.45	3.48	3.03	1.58	1.56	3.55	3.61
7	Prog.[5]	Nov.	No	21.3	20.8	4.45	4.40	3.20	3.05	1.61	1.57	3.64	3.69
8	Unsh.	None	No	21.5	20.5	4.40	4.45	3.22	3.22	1.61	1.64	3.60	3.48
mean				21.4	21.3	4.53	4.51	3.52	3.59	1.69	1.66	3.64	3.63
stand.dev., %mean				10	10	11	11	23	23	10	9	26	23
minimum				16.0	17.0	3.75	3.60	2.30	2.00	1.42	1.39	2.8	3.0
maximum				25.0	26.0	5.80	5.70	5.60	5.70	2.14	2.11	4.6	4.4
Ftest				2.4	1.2	0.6	0.5	1.5	1.3	6.1	7.0	3.5	3.7
prob. F				0.05	0.33	0.72	0.84	0.21	0.31	<0.01	<0.01	<0.01	<0.01
L.S.D.$_{0.05}$[6]				2.0	—	—	—	—	—	0.14	0.12	0.5	0.4
Fraser Fir													
1	10	Nov.	No	19.0	19.5	5.60	5.35	4.20	4.35	1.50	1.54	3.72	3.70
2	12	Aug.	No	19.3	18.8	5.50	5.00	4.20	4.20	1.55	1.53	3.77	3.74
3	12	Nov.	No	19.0	19.5	6.00	5.78	4.35	4.22	1.60	1.56	3.69	3.76
4	12	Nov.	Yes[4]	21.2	21.3	6.70	6.59	5.00	4.75	1.74	1.76	4.15	4.10
5	12	Mar.	No	19.0	19.5	5.40	5.42	3.82	3.78	1.62	1.60	3.83	3.78
6	15	Nov.	No	18.9	19.4	5.75	5.80	3.60	3.88	1.51	1.44	3.75	3.83
7	Prog.[5]	Nov.	No	19.0	19.3	5.65	5.55	3.60	3.40	1.58	1.47	3.70	3.80
8	Unsh.	None	No	18.5	17.0	5.30	5.35	4.30	4.20	1.44	1.31	3.72	3.78
mean				19.2	19.3	5.73	5.57	4.13	4.03	1.57	1.52	3.70	3.71
stand.dev., %mean				10	9	10	10	22	22	11	10	16	15
minimum				16.0	15.0	4.50	4.40	2.65	2.60	1.10	1.14	2.9	3.2
maximum				22.8	23.0	7.40	7.30	6.70	6.90	2.01	1.88	4.5	4.5
Ftest				3.8	3.7	3.6	3.9	2.3	2.1	4.9	5.9	4.2	4.3
prob. F				<0.01	<0.01	<0.01	0.07	0.08	<0.01	<0.01	<0.01	<0.01	<0.01
L.S.D.$_{0.05}$[6]				1.0	2.1	0.63	0.66	—	—	0.19	0.16	0.4	0.4

[1] Lengths to which terminal shoots were supposed to be cut as part of the study.

[2] Average weight of stems and needles of four-inch-long foliage samples from the upper one-third of the tree.

[3] Foliage color rating: 1 = yellow; 2 = green-yellow; 3 = yellow-green; 4 = green; 5 = blue-green

[4] Trees in Treatment 4 were fertilized with 200 pounds of actual nitrogen/acre in March of each year.

[5] Treatment 7: "Progressive" treatment trees were designated to be sheared to leader lengths of: 1st year = 18 inches; 2nd year = 14 inches; 3rd and 4th years = 12 inches; 5th year = length to give an even, conical appearance to trees.

[6] Least Significant Difference at 5% probability level for comparing differences between treatment means; values are not give for variables where differences were not statistically significant.

Table 5. Tree Quality and USDA Grades for West Virginia Balsam (Canaan) Fir and Fraser Fir.

Treatment				Tree	Tree	Defects/Tree[3]		USDA Grades[4]				
No.	Lead. Lgth[1] in.	Time	Fert.	Taper[2] %	Dnsty %	Minor ---------no.--------	Notice.	Ave. Grade	Prem. (4) --------------------%-------------------	No. 1 (3)	No.2 (2)	Cull (1)
West Virginia Balsam Fir												
1	10	Nov.	No	59.0	85.3	1.23	0.00	4.00	100.0	0.0	0.0	0.0
2	12	Aug.	No	54.0	77.5	1.60	0.25	3.60	91.7	8.3	0.0	0.0
3	12	Nov.	No	51.8	75.8	1.68	0.25	3.25	58.5	41.5	0.0	0.0
4	12	Nov.	Yes[5]	53.0	79.8	1.73	0.18	3.35	41.8	50.0	8.2	0.0
5	12	Mar.	No	54.0	78.0	2.00	0.25	3.17	50.0	25.0	25.0	0.0
6	15	Nov.	No	51.5	76.0	1.88	0.33	3.35	50.3	33.0	16.7	0.0
7	Prog.[6]	Nov.	No	47.0	70.0	2.20	0.50	3.10	33.5	41.5	25.0	0.0
8	Unsh.	None	No	51.5	36.3	0.00	10.58	1.00	0.0	0.0	0.0	100.0
mean				52.7	72.3	1.54	1.54	3.10	44.9	32.2	10.4	12.5
stand. dev., % mean				8	21	64	227	49	79	85	206	269
minimum				42.0	30	0	0	1.00	0	0	0	0
maximum				63.0	87.0	3.70	11.70	4.00	100	0	0	100
F test				6.6	34.6	2.5	212.8	17.3	5.0	5.6	1.2	[8]
prob. F				<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	0.36	[8]
L.S.D.$_{0.05}$[7]				3.9	7.6	1.27	0.74	0.63	39.7	28.9	29.1	[8]
Fraser Fir												
1	10	Nov.	No	55.3	79.8	1.38	0.30	3.60	58.5	41.5	0.0	0.0
2	12	Aug.	No	49.0	77.5	1.60	1.03	3.40	41.7	58.3	0.0	0.0
3	12	Nov.	No	50.8	72.0	1.58	1.00	3.17	33.4	41.8	24.8	0.0
4	12	Nov.	Yes[5]	50.5	78.0	1.50	0.68	3.20	33.5	50.0	16.5	0.0
5	12	Mar.	No	48.5	77.3	1.85	0.68	3.07	29.0	50.0	21.0	0.0
6	15	Nov.	No	46.5	72.0	1.70	1.03	3.05	20.8	62.5	16.7	0.0
7	Prog.[6]	Nov.	No	45.7	68.5	2.00	0.68	2.92	33.4	41.5	25.1	0.0
8	Unsh.	None	No	55.4	35.8	0.00	12.30	1.00	0.0	0.0	0.0	100.0
mean				50.2	69.2	1.45	2.21	2.93	31.3	44.2	12.0	12.5
stand. dev., % mean				8	21	68	178	40	97	75	158	269
minimum				42.0	32.0	0	0	1.00	0	0	0	0
maximum				58.0	90.0	3.30	3.30	4.00	100	100	67	100
F test				6.6	21.3	2.6	142.4	22.5	1.42	1.7	1.5	[8]
prob. F				<0.01	<0.01	0.04	<0.01	<0.01	0.24	0.16	0.21	[8]
L.S.D.$_{0.05}$[7]				3.87	8.98	1.13	1.00	0.54	41.2	45.7	26.5	[8]

[1] Lengths to which terminal shoots were supposed to be cut as part of the study.
[2] Defects: Each tree evaluated in accordance with criteria outlined in Appendix Table 1.
[3] Taper: Tree Width/Tree Height for measurements made at the conclusion of the study.
[4] USDA Grades: Each tree graded in accordance with criteria outlined in Appendix Table 2. For the "average" grade and coding for statistical analyses, designations used were: 4 = premium, 2 = No. 3, 3 = No. 2, 1 = Cull.
[5] Trees in Treatment 4 were fertilized with 200 pounds of actual nitrogen/acre in March of each year.
[6] Treatment 7: "Progressive" treatment trees were designated to be sheared to leader lengths of: 1st year = 18 inches; 2nd year = 14 inches; 3rd and 4th years = 12 inches; 5th year = length to give an even, conical appearance to trees.
[7] Least Significant Difference at 5% probability level for comparing differences between treatment means; values are not given for variables where differences were not statistically significant.
[8] The distribution of data for percentages of "cull" trees did not meet the criteria for statistical analyses; thus, F values, probabilities of F, and L.S.D.s were not calculated.

of Christmas trees. For both West Virginia balsam and Fraser fir, the average taper for trees in all treatments, including those that were unsheared, was within the 40 percent to 100 percent range required for the U.S. Premium grade. In addition, standard deviations, a measure of variation within treatments, were relatively small, averaging just 8 percent of the overall mean for each species (Table 5, Appendix Table 2).

For individual shearing treatments, highest taper was found on trees on which terminals had been sheared to the shortest (10-inch) lengths (Figure 3), while the narrowest taper occurred on trees on which terminal shoots had been sheared using the "progressive" treatment (Table 5, Figure 6). At least some of these differences were related to the five-foot spacing within rows at which trees were planted.

To provide uniform taper and density, it was necessary to shear trees to a final width of approximately 5 feet; thus, the shorter the terminals and total heights of trees, the greater the taper. Unsheared trees were the exception; although they were the tallest, limbs in the lower whorls often overlapped those of adjacent trees, resulting in somewhat higher taper but uneven lengths and incomplete whorls that resulted in many other grading defects (Figure 4).

Tree Density

To qualify for the USDA Premium grade, density of trees of Fraser fir must be at least 70 percent, while for West Virginia balsam it must be at least 80 percent (Appendix Table 2). In this study, densities of trees of West Virginia balsam fir and Fraser fir were approximately the same, with overall averages of 72.3 and 69.2 percent, respectively.

For Treatments 1 to 7 for which trees had been sheared, densities were highest where terminals were cut to 10-inch lengths (Figure 3), with an average of 85.3 percent for West Virginia balsam and 79.8 percent for Fraser fir, and were lowest (70.0 and 68.5 percent, respectively) for trees which received the "progressive" treatment (Figure 6).

For both species, there was considerable tree-to-tree variation within treatments, as indicated by the relatively high standard deviations of 21 percent of the overall averages (Table 5). Average density of unsheared trees (Treatment 8) for both species was approximately 30 percent which, independent of other factors, would give trees a Cull grade (Appendix Table 2, Figure 4).

Numbers of Defects per Tree

The USDA standards for evaluating quality of Christmas trees use several types of defects and the extent to which they affect the appearance of trees to establish U.S. Premium, No. 1, No. 2, and Cull Grades (Appendix Table 2). Numbers of "minor" defects were generally slightly but not significantly higher on trees of West Virginia balsam than on those of Fraser fir, with overall averages of 1.54 and 1.45 per tree, respectively. Similarly, except for those trees on which terminals had been sheared to 10-inch lengths, minor defects for individual shearing treatments were generally slightly higher on trees of West Virginia balsam fir, with ranges in numbers from 1.60 to 2.20 and 1.50 to 2.00 for the two varieties (Table 5, Appendix Table 1).

Although the types of minor defects of trees are not detailed in Table 5, much of the difference between the two varieties was related to the lower density requirements for Fraser fir. Other minor defects included uneven density (Figure 7) and small holes or gaps in the foliage (Figure 8). As shown in Table 5, there was considerable tree-to-tree variation in numbers of minor defects as indicated by the very large standard deviations of 64 percent for West Virginia balsam and 68 percent for Fraser fir.

The numbers of "noticeable" or major defects was consistently lower on sheared trees of West Virginia balsam than on Fraser fir, with averages of 1.54 and 2.21, respectively, for the two varieties (Table 5, Appendix Table 1), with defects on unsheared trees accounting for many of the problems in "average" tree quality. Within each variety, tree-to-tree variation in noticeable defects was very great, as indicated by the large standard deviations of 227 and 178 percent of the overall means for West Virginia balsam and Fraser fir, respectively.

For trees that were sheared, noticeable defects ranged from 0.00 to 0.50 and 0.30 to 1.03 per tree, respectively, for West Virginia balsam and Fraser fir, with lowest numbers for trees on which terminal shoots were cut to 10-inch lengths. Differences in noticeable defects between West Virginia balsam and Fraser fir were primarily related to higher occurrences of moderately uneven density (Figure 7) and holes or spaces that were considerably out of proportion with uniform branch characteristics on trees of Fraser fir (Appendix Table 1, Figure 9).

The higher occurrence of irregularities in the foliage of Fraser fir was probably related to differences in numbers of internodal limbs (discussed earlier) and branch angles on trees of the two varieties. Although it was not measured in this study, previous research found that trees of West Virginia balsam fir generally had more "upswept," ascending branch angles than those of Fraser fir (Figure 2) which tend to cover the terminal shoot, thereby helping

Figure 7. Uneven density in foliage of Fraser fir tree.

Figure 8. Small holes in foliage of West Virginia balsam fir tree.

Figure 9. Noticeable holes in foliage of West Virginia balsam (left) and Fraser fir (right) trees.

to reduce "holes" and other irregularities in foliage density that might decrease tree grade.

Higher numbers of internodal limbs and more ascending branch angles on trees of West Virginia balsam fir can also create potential problems. Multiple leaders and multiple main stems are other defects that affect Christmas-tree quality. None of the sheared trees in the study had those defects because care was taken to leave only one leader on trees. However, it was observed that trees of West Virginia balsam fir had a tendency to have more multiple leaders before trees were sheared than did those of Fraser fir and care should be taken to remove them (Figure 10).

USDA Grades of Trees

In analyses of data for USDA grades for trees (U.S. Department of Agriculture, 1989), those graded as Premium, No. 1, No. 2, and Cull were assigned values of 4, 3, 2, and 1, respectively; thus, the higher the value, the better the tree (Table 5, Appendix Table 2). The overall average USDA grade for trees of West Virginia balsam fir (3.10) was slightly higher than that for Fraser fir (2.93) — with both being near the USDA No. 1 grade of 3.0.

For trees on which terminals were sheared to different lengths, average grades were consistently better for West Virginia balsam fir than for Fraser fir, with ranges from 3.10 to 4.00 and 2.92 to 3.60, respectively, with highest average grades for trees with terminals sheared to 10 inches — the treatment for which there were the fewest number of minor and noticeable defects (Figure 3). Average grades of sheared trees were lowest for trees sheared using the "progressive" treatment for which average numbers of minor and noticeable defects were highest (Figure 6). All unsheared trees

Figure 10. Multiple leaders on West Virginia balsam (left) and Fraser fir (right) trees.

in the study were graded as Culls (1.0) because of a variety of multiple defects on individual trees (Table 5, Figure 4).

For trees on which terminals were sheared to 12-inch lengths at different times of the year (August, November, and March), with or without nitrogen fertilization, average grades for both varieties were highest for trees sheared in August and lowest for those sheared in March (Table 5). As noted previously, nitrogen fertilization improved needle lengths, twig weights, and foliage color of trees of both varieties.

However, because the overall foliage quality of trees was judged to be within "characteristics typical of the species" as used in the grading standards (Appendix Table 2), those improvements were not reflected in the grades assigned to individual trees and, as a result, there were no apparent differences in average grades of fertilized and unfertilized trees that were sheared in November.

Differences in "average" grades of trees were reflected in the proportion of trees having different USDA grades. For West Virginia balsam fir, 44.9 percent of individual trees were graded as Premiums, 32.2 percent as No. 1s, 10.4 percent as No. 2s, and 12.5 percent as Culls. For Fraser fir, comparable values were 31.3, 44.2, 12.0, and 12.5 percent.

For both varieties, the highest number of Premium trees was recorded for those on which terminals were sheared to 10-inch lengths — 100 percent for West Virginia balsam and 58.5 percent for Fraser fir. None of the individual trees that were sheared were graded as Culls, while all unsheared trees were Culls (Table 5).

Higher USDA grades for trees of West Virginia balsam fir were a reflection of the types of "minor" and "noticeable" defects on trees and the numbers and locations of those defects on the four different "faces"of trees. As outlined in Appendix Tables 1 and

2, U.S. Premium trees can not have any noticeable defects and not more than two minor defects, one on three adjacent faces and a second on the fourth face. To be graded as a U.S. No. 1 tree, there can be one noticeable defect on one face and not more than two minor defects on the remaining three faces.

As discussed previously, sheared trees of West Virginia balsam fir had fewer noticeable defects than did those of Fraser fir and those that did occur were more commonly confined to only one face. Additionally, although trees of West Virginia balsam fir had slightly higher numbers of minor defects, they tended to be more evenly distributed over the four faces (Table 5).

Additional Observations

As described in the *Methods* section, trees on individual plots were randomly assigned to treatments without regard to growth rate, bud set, or branch angle. These characteristics can markedly affect how a tree responds to shearing and, as noted by Brown (1999), these traits vary widely in West Virginia balsam fir.

Since the inception of this study, experience and observations by the authors and experience by growers have suggested that careful evaluation of individual trees can substantially improve the quality of trees sheared with longer terminals. Specifically, individual West Virginia balsam fir exhibiting good terminal growth and bud set and relatively upswept lateral branaches can produce a quality tree when sheared with longer terminals, while those with poorer terminal growth, bud set, and/or flatter lateral branches require a shearing strategy with relatively shorter terminals (Figure 11).

In fact, premium quality trees 8 to 11 feet in height can be produced in seven to eight

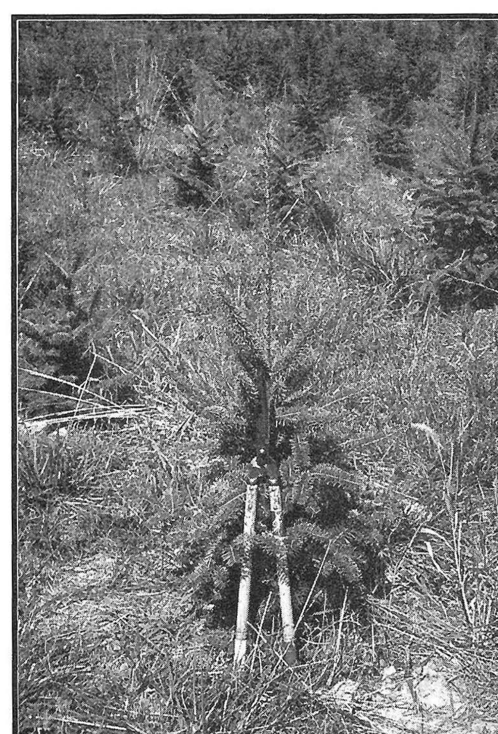

Figure 11. Trees of West Virginia balsam fir having (left) a short terminal shoot and slightly ascending branch angles for lateral limbs and (right) a longer terminal shoot and pronounced ascending branch angles for laterals.

years from appropriately selected trees growing on good sites with good weed control and fertility (Figure 12). Depending on the individual tree, terminals in some years may be up to 20 inches or more in length. It is important to note, however, that this strategy does not necessarily produce a marketable tree at shorter heights. Trees sheared with long terminals require sufficient time for the internodal branches to fill and develop the density and uniformity necessary for a marketable tree.

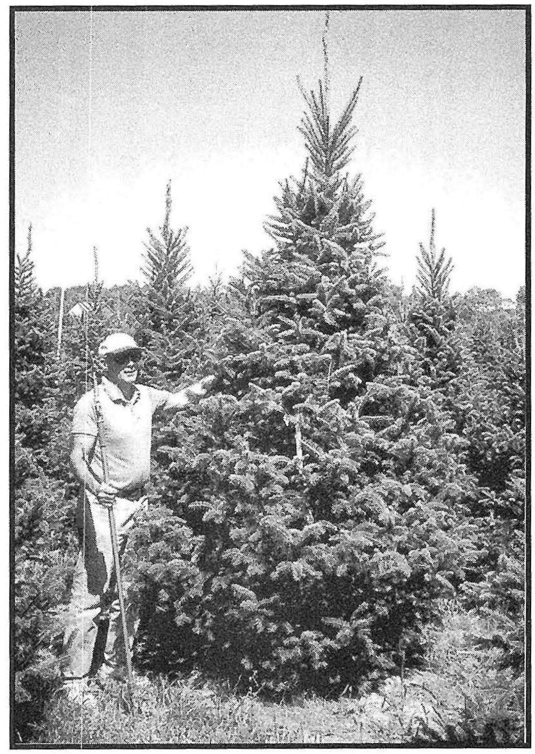

Figure 12. Seven-year-old West Virginia balsam fir produced from a rapidly growing tree on a good site and having good bud set and strongly ascending lateral branches.

The importance of carefully selecting individual trees if longer terminals are to be left cannot be overemphasized. If West Virginia balsam fir are sheared with longer terminals without selecting individual trees suited to that strategy, the quality of trees produced will probably resemble that achieved in this study with the progressive shearing treatment, or worse, if longer terminals are left.

It is probable that individual Fraser fir could also be selected for production of Christmas trees with shorter rotations using the same general criteria described for West Virginia balsam fir. However, as indicated previously, trees of Fraser fir generally have fewer lateral buds and limbs on terminal shoots, branch angles are somewhat "flatter" than on West Virginia balsam fir, and it would probably take an additional one to three years to produce high-quality 8- to 11-foot trees.

Summary and Conclusions

Results of this study indicate that although trees of West Virginia balsam and Fraser fir can be successfully sheared into quality Christmas trees from mid-summer to early spring, shearing soon after shoot growth is completed and stem tissue begins to harden in mid- to late-summer can result in improved quality as reflected by higher numbers of U.S. Premium and U.S. No. 1 trees, particularly when compared with trees sheared in late winter/early spring.

Specific data collected as part of the study does not provide conclusive evidence of why this occurs, because there were no trends in shoot growth after shearing, numbers of internodal buds and limbs, or tree density related to time of shearing. Based on results in other studies with the pine species (Brown, 1960; Brown, 1964; Brown, 1984), it is possible that when shoots are sheared in late summer when growing conditions are more favorable and before stem tissue begins to harden, internodal buds which are already present along the shoots of the firs can develop/ enlarge and produce more vigorous internodal limbs the following growing season.

Also, as noted in previous studies with the pines (Brown, 1981), the shorter terminal shoots of West Virginia balsam and Fraser fir were sheared, the higher the tree quality. In this study, for those with terminals sheared to 10-inch lengths, 100 percent of West Virginia balsam and 59 percent of Fraser fir were graded as Premiums, while for those sheared using the "progressive" treatment, approximately 33 percent of trees of both varieties were graded as Premiums.

However, it should be noted that shearing terminal shoots to shorter lengths increases the time needed to produce harvestable trees; for those on which terminals were cut to 10-inch lengths, trees began to reach harvestable size after five shearings and eight years in the field, while those on which terminals were cut to 15 inches and those sheared using the "progressive" treatment began to reach harvestable size after three shearings and six years in the field.

It is also important to remember that individual trees in this study were randomly assigned to shearing treatments and were not selected based on growth rate, bud set, or lateral branch angle. Experience separate from this study has demonstrated that West Virginia balsam fir trees exhibiting good growth rate and bud set and upward-swept lateral branches can be sheared with terminals even longer than those used in this study and still produce high-quality trees. Such shearing strategies, however, necessitate that trees be growing on good sites with adequate fertility and good weed control.

Annual applications of nitrogen fertilizer had no effect on shoot growth, numbers of internodal buds and limbs, tree density, or overall tree quality as specifically used in assigning USDA grades to trees in this study. However, fertilizing did have some very beneficial effects on tree quality as reflected in foliage characteristics of both West Virginia balsam and Fraser fir, including increased needle lengths; heavier, more dense foliage; and better needle color. These are all traits that can help the overall appearance and marketability of trees.

Other research at the Ohio Agricultural Research and Development Center has shown that annual applications of fertilizer may not be needed to improve foliage quality on harvestable trees; rather, benefits of nitrogen applications are usually effective for at least two years, and applications made in the spring of the year prior to harvest will improve foliage characteristics of the two years of needles that are most visible on trees (Brown, 1976; Brown, 1998a; Brown, 2000a; Brown and Vimmerstedt, 1983; Keller, 1980).

For this study, USDA Standards for grading Christmas trees were used to evaluate the effects of various defects on trees and to assign a "quality" value to individual trees. Results found that because of higher numbers of internodal lateral limbs and more ascending branch angles, overall tree quality was generally somewhat higher for trees of West Virginia balsam than for those of Fraser fir. For individual Christmas tree growers, this may or may not result in better sales and/or higher prices.

In Ohio and many other states, most growers use their own subjective criteria rather than USDA grades to judge tree quality, and Fraser fir is well established as THE PREMIUM TREE on the Christmas-tree market. Excellent foliage quality, including the color of the upper and lower surfaces of needles, "stiffer" limbs that support decorations without sagging, and needle retention on cut trees (Heiligmann and Brown, 1997) contribute to that position.

As noted earlier, West Virginia balsam "Canaan" fir is relatively new to the Christmas-tree market and is still establishing its place in the market. Major factors influencing increased planting of that variety include adaptability to a wider range of site conditions, including "wetter" sites, and later bud break than many of the other single-needled conifers, including Fraser fir and Douglas-fir (Brown, 1976; 1983b; 1988; 1998b; 1999; 2000a; 2000b).

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Appendix

Appendix Table 1. Classification of Defects Used in Grading Trees of West Virginia Balsam (Canaan) and Fraser Fir.[1]

Factor	Minor Defect	Noticeable Defect	Culling Defect
Density	Slightly uneven	Moderately uneven	Severely uneven
Curvature Main Stem	Visible crook 4" or less from vertical	Visibly curved >4" but <6" from vertical	Curved >6" from vertical
Broken Branches	1 broken whorl near main stem	Broken leader or >1 broken whorl branch	Main stem broken below top whorl or >3 broken branches near trunk
Physical Damage	Slight	Moderate	Severe
Multiple Leaders	Multiple leaders	Crows nest	Multiple main stems
Extra Long Branches	Branch >10" longer than others in same whorl	N/A	N/A
Weak Lower Branches	Free from	Affecting up to 3/4 of branches on bottom whorl	Affecting >3/4 branches on bottom whorl
Incomplete Whorl of Branches	<1/4 branches missing in any one whorl	1/4 but <1/2 branches missing in any one whorl	>1/2 branches missing in a whorl or missing branches create a shelf
Holes or Gaps in Tree	Free from	Hole or space considerably out of proportion with uniform branch characteristics of remainder of the tree	Shelf or decided gap or space between whorls noticeable on 2 or more faces
Gooseneck	Free from	Free from	Any gooseneck
Loss of Needles	Slight	Moderate	Severe

[1] Descriptions of minor, noticeable, and culling defects used in grading Christmas trees. From: *United States Standards for Grades of Christmas Trees,* USDA Agricultural Marketing Service, 1989.

Appendix

Appendix Table 2. U. S. Standards Used for Grading Trees of West Virginia Balsam (Canaan) and Fraser Fir.

Criteria	U.S. Premium	U.S. No. 1	U.S. No. 2	Cull
Characteristics Typical of Species	Yes	Yes	Yes	No
Normal Taper (Not <40% or >100%)	Yes	Yes	Yes	No
Fresh	Yes	Yes	Yes	No
Cleanliness	Clean	Fairly Clean	Fairly Clean	No
Healthy	Yes	Yes	Yes	No
Well-Shaped	Yes	Yes	Yes	No
Density:				
WV Balsam	80-100%	60-80%	40-60%	<40%
Fraser Fir	70-100%	50-70%	40-50%	<40%
Defect Allowed	Three faces with not >1 minor; remaining face with not >1 minor.	Three faces with not >2 minor; remaining face with not >1 noticeable.	Two adjacent faces with not >3 minor; remaining faces >2 noticeable.	Does not meet U.S. No. 2 standards.

[1] Criteria used for establishing grades of trees. From: *United States Standards for Grades of Christmas Trees,* USDA Agricultural Marketing Service, 1989.

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